

Shallow Water Mid-Frequency Research and FY06 Experiment

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LONG-TERM GOALS

To Understand mid-frequency (1-10 kHz) acoustics in shallow waters through measurements and modeling, including propagation, reflection, and forward- and backscatter. The top-level goals of this effort are to understand what are the important environmental processes, which impact mid-frequency sonar performances in shallow water environments; and to develop means to efficiently collect those environmental data.

OBJECTIVES

Participate in the LEAR acoustics field experiment in 2006 to investigate mid-frequency (1-10 kHz) acoustics interacting with environments.

Acoustics objectives and tasks:

1. Direct-path bottom backscatter – what are the most important physical mechanisms?
Equipment: APL 32 element vertical line array.
2. Single interface forward scatter – what are the most important physical mechanisms (with by Peter Dahl). Equipment: APL's MORAY/BASS.
3. Multiple boundary interactions (with by Peter Dahl) – Can we successfully combine our knowledge of single interactions to predict the results of a small number of surface and bottom interactions? Equipment: combination of equipments from 1 and 2.
4. Long-range (10–20 km) propagation – can multiple interactions with rough boundaries actually simplify the field present at long ranges?

Environmental measurements

Environmental measurements will include in situ and remote sensing components. It is important to cover all relevant environments with adequate sampling. The environments are the sea surface (Buoys, Graber and Dahl), the water column (Internal waves by Henyey and Moum), and the sea bottom (APL and Turgut of NRL).

APPROACH

Starting with assumptions and hypotheses based on current knowledge of the field, we will combine acoustics measurements with modeling efforts using the measured environmental parameters to

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achieve quantitative model/data comparisons of sound fields interacting with bottom, surface and the water column. We will start from a local area on the order of 100 m by 100 m, and study single interactions of sound with the bottom and the surface over space and time. In each case, we will make detailed model/data comparisons. We will then investigate multiple (2 – 3 bounces) interactions of sound field with the bottom and surface. The point here is to combine the modeling results dealing with individual interaction into an integrated model. Finally, we will study long- range propagation, multiple forward scattering, and reverberation issues over a range of 10–20 km. By necessity, the experiment will consist of an acoustics part and an environmental measurement part. We will emphasize carrying out environmental measurements at sufficient resolution to properly answer the acoustic questions to be addressed. The acoustics topics include:

1. Single boundary interaction backscattering – what are the most important physical mechanisms?
2. Single boundary interaction forward reflection and forward scattering – what are the most important physical mechanisms?
3. Multiple boundary interactions – Can we successfully combine our knowledge of single interactions to predict the results of a small number of surface and bottom interactions?
4. Long-range (10–20 km) propagation and reverberation – can multiple interactions with rough boundaries actually simplify the field present at long ranges?

Environmental measurement topics will include in situ and remote sensing components. They are:

1. In-sediment measurements of sound speed in the bottom over a depth of 3 m with spatial resolution of 5-10 cm in depth (Equipment: APL “SAMS”).
2. In situ measurements of bottom roughness and volume heterogeneity over several meters with horizontal spatial resolution of 1–2 cm and vertical resolution of 1 mm (IMP2 from APL).
3. In situ measurements of sea surface roughness spectra and wind speed (Dahl).
4. Measurement of nonlinear littoral internal waves using a CTD chain vs. time and space (Henyey).
5. Analysis of cores to obtain sediment density, attenuation coefficient, and sound speed. (Chapman, Goff and Turgut).
6. Remote sensing using chirp sonar to estimate sediment geo-acoustic properties over large areas. (Turgut).
7. Remote sensing of geo-acoustic parameters using ambient noise (APL vertical array).
8. Remote sensing of bottom topography data over large areas using side-scan multi-beam sonar (to be identified).

In addition, we will investigate how to estimate key environmental parameters using only acoustic fields from reflection and backscatter. This will be accomplished by optimizing forward model parameters with acoustic data. For this to be successful, ground truth data (SAMS) in at least one spot is critically necessary.

WORK COMPLETED

Building equipments and associated electronics systems was one of the two major efforts for this fiscal year. Simulations and modeling of fieldwork are the other. The SAMS is a new sediment sound speed measurement system, which will take in situ data as deep into sediments as three meters, has been fully designed. Also underway is a numerical simulations tool to assist the SAMS deployment configurations and data processing. Progress on the electronics system that supports the 32 element vertical line array has been made on schedule. Simulations on sound scattering from internal solitary waves have yielded interesting results, which were done together with Henyey, and were reported in the NLIWI workshop. A scientific paper on this subject is expected to be finished before the LEAR experiment. A major part of the field work will be a collaboration with Peter Dahl. Extensive planning has been accomplished – an hour-by-hour field schedule has been thoroughly worked on. Overall, all preparations for the LEAR experiment are on schedule.

RESULTS

One major result is found through simulations of sound interaction with solitary waves. This work is jointly done with Frank Henyey funded by ONR Oceanography. When a ray of sound travels at small grazing angles encounters a packet of solitary waves, the waves can change the direction of the rays so much that the otherwise water column bound rays can change course to hit the bottom. Consequently, after hitting the bottom, the rays will be backscattered, resulting in a false target. This effect will be studied in detail in the LEAR experiment.

Another interesting result is a collaboration with Dan Rouseff. We worked on effect of internal waves on ambient noise notch. We found through analyzing ASIAEX data that background internal waves can fill in the noise notch. A paper is under final preparation.

A wave propagation paper is in preparation that deals with sound propagation in very shallow water (near beach). This work has significance in that range-dependent propagation can be tested against models with accurate and sufficient environmental data, which are difficult to obtain in typical shallow waters (order 100m).

Finally, to understand sea bottom using an active mid-frequency source and a vertical line array, a simulation has been conducted and we now have the ability to deal with bottom scatter in both near as well as far field. This work will be used in analysis of next year's field data.

IMPACT/APPLICATIONS

While the LEAR experiment next year will address many basic science questions, our goal is to improve mid-frequency sonar performance in shallow waters environments. We anticipate impacts in two areas: First, because we will measure all relevant environmental parameters influencing sound waves, we will be able to identify the important environmental process, hence providing the applied community what environmental process to focus on. Second, we will explore methods such chirp sonar and ambient noise to quantitatively measure bottom parameters. Third, the study on sound interaction with internal waves could provide insight in reverberation clutter.

RELATED PROJECTS

NonLinear Internal Wave Initiative (NLIWI). <http://www.nliwi.org>

PUBLICATIONS

D. Tang, “Numerical simulation of scattering from a rough sea bottom measured on a vertical line array,” accepted by JASA pending revisions.

D. Rouseff and D. Tang, “Effect of environmental variability on the ambient noise notch,” in preparation for JASA.

D. Tang, “Wave propagation in very shallow water experiment using a boat as source”, in preparation for JASA